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# A Study of Cladonia cryptochlorophaea and Morphologically Similar Species in Illinois, Indiana, and Wisconsin

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# A STUDY OF CLADONIA CRYPTOCHLOROPHAEA AND MORPHOLOGICALLY SIMILAR SPECIES IN ILLINOIS, INDIANA, AND WISCONSIN

(TITLE)

BY

SCOTT S. WILCER

## THESIS

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# A STUDY OF *CLADONIA CRYPTOCHLOROPHAEA* AND MORPHOLOGICALLY SIMILAR SPECIES IN ILLINOIS, INDIANA, AND WISCONSIN

by

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B.S. in Environmental Biology, Eastern Illinois University
B.S. in Botany, Eastern Illinois University

**Abstract of a Thesis**

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Botany at the Graduate School of Eastern Illinois University, Charleston, Illinois, 1984.

**ABSTRACT**

Collections of Cladonias with cup-shaped podetia were made in Illinois, Indiana, and Wisconsin in order to determine the distribution of an atranorin-containing variant of *Cladonia cryptochlorophaea,* which was discovered in 1982 in Coles County, Illinois by Cheryl Cunningham. A second objective was a distributional study of the Cladonias having cup-shaped podetia in the same three state area.

A total of 591 specimens were collected from the three states. The collection areas for Illinois were: Jackson Hollow in Pope County, Giant City State Park and Touch of Nature Interpretive Center in Jackson and Williamson Counties, Starved Rock State Park in LaSalle County, and Sand ridge State Park in Mason County. The three collecting locations in Indiana were: Koontz Lake in Starke County, Turkey Run State Park in Parke County, and Fern Cliff in Putnam County. In Wisconsin, five areas were collected from: Tamarack Road in Walworth County, Palmyra Prairie in Waukeska County, a county roadside park in Sauk County, Whitford Farm in Marquette County, and Lone Rock DNR Unit in Richland County. The TLC method and microcrystal tests were utilized for identification of lichen substances.

The total numbers of collections for each species were: *Cladonia grayi* - 343 specimens, *Cladonia pleurota* - 112 specimens, *Cladonia chlorophaea* - 73 specimens, and *Cladonia*

*cryptochlorophaea* - 63 specimens. 33 of the 63 specimens of *C. cryptochlorophaea* contained atranorin. All three states yielded specimens of this atranorin - containing variant. The prescence or absence of atranorin was independant of that of fumaroprotocetraric acid, another accessory substance.

The distributional study showed that *C. grayi* was the most frequently encountered chemotaxon.

For *C. chlorophaea,* there was a higher frequency in Wisconsin than the more southern areas in Illinois and Indiana.

*C. pleurota* showed a preference for harder substrates such as sandstone over loose sand or sandy soil. *C. cryptochlorophaea* was always collected in low frequencies.

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# INTRODUCTION

*Cladonia cryptochlorophaea* Asah, is a lichen with a cup shaped podetium characterized by the presence of cryptochlorophaeic acid, either alone or in combination with fumaroprotocetraric acid. However, recently Cunningham (1982) reported that some specimens of this species from Coles and Clark counties in East-central Illinois also contained atranorin. The major objective of this present study is to determine if this atranorin-containing chemotaxon of *C. cryptochlorophaea* has a wider distribution than that reported by Cunningham. A secondary objective is a distributional and frequency study of the Cladonia species having cup-shaped podetia in Illinois, Indiana and Southern Wisconsin.

# I. TAXONOMY

The Cladonias having cup shaped podetia were originally classified on the basis of morphology. For those having red apothecia, Fink (1910) recognized *Cladonia coccifera* (L.) Willd. characterized by coarse areoles, and the variety *pleurota* (Floerke) Schaer with soredia instead of areoles. For those with brown apothecia, Fink characterized *Cladonia pyxidata* (L.) Hoffm. by the presence of areoles and the variety *chlorophaea* (Spreng) Floerke as sorediate, while the variety *pocillum* (Ach) Flot. was defined by a lack of both soredia and areoles. Later (1935), he did not recognize the variety *chlorophaea* as being distinct from *Cladonia pyxidata.*

A. Smith's (1918) treatment of the group was similar to that of Fink, with *C. pleurota* recognized as a subspecies rather than a variety of *C. coccifera,* and both *C. chlorophaea* and *C. pocillum* as varieties of *C. pyxidata.*

Later, chemical content was used extensively to separate the sorediate cup cladonias with brown apothecia into taxonomic categories. Zopf (1908), according to Ahti (1966), distinguished *C. chlorophaea* from *C. pleurota* by the presence of chlorophaeic acid in the former and lack of it in the latter. Zopf's chlorophaeic acid is the equivalent of the same substance now called grayanic acid

according to Culberson (1969).

However, Evans (1944) suggests that Zopf's chlorophaeic acid was an impure substance derived from material containing several lichen acids.

Sanstede (1931) differentiated specimens on the basis of taste, with those having a bitter taste due to fumaroprotocetraric acid classified as *C. chlorophaea* (Flk.) Spreng., and those possessing a mild taste and containing no fumaroprotocetraric acid as *Cladonia grayi* Merr. ex. Sanst.

Sanstede's distinction was modified by Asahina (1940), who discovered three addiitonal acids, grayanic, cryptochlorophaeic, and merochlorophaeic. On the basis of this discovery he expanded the group to four species: *C. chlorophaea, C. grayi, Cladonia cryptochlorophaea* Asah., and *Cladonia merochlorophaea* Asah. Subsequently, Asahina (1941) determined that specimens named *C. chlorophaea* f. *conistea* Del. contained atranorin as the characteristic lichen substance, and fumaroprotocetraric acid as an accessory substance. In the same paper, he reported the discovery of substance H, now known as bourgeonic acid, in specimens he determined as *Cladonia conista* (Ach.) Robb. The addition of this sorediate cup cladonia with brown apothecia brings the number of species recognized by Asahina to five. Evans (1944), as well as Hale and Culberson (1966) and Hale (1969), accepted Asahina's classification of the group.

Thompson (1967) recognized those species designated by Asahina, although he suggests that it might be more satisfactory to treat most of them as chemical strains

of C. chlorophaea. Following the definitions given by Evans (1944), he present five species: *C. chlorophaea*-fumaroprotocetraric acid only, *C. grayi*-grayanic acid with or without fumaroprotocetraric acid, *C. merochlorophaea*- merochlorophaeic acid, *C. cryptochlorophaea*-cryptochlorophaeic acid with or without fumaroprotocetraric acid, and *C. conista* with substance H and fumaroprotocetraric acid. In addition, specimens containing only atranorin were treated as *C. chlorophaea* f. *conistea*, not to be confused with *C. conista*.

Two other chemical variants have been reported. One of these is the sorediate *Cladonia perlomera* Culb. and Krist., which contains merochlorophaeic, 4-O-methylcryptochlorophaeic, and perlatolic acids and is reported to have an eastern coastal range in the United States. The other is *C. magyrica* Vain. containing fumaroprotocetraric acid and atranorin and having an eastern European range. This latter species is chemically similar to *C. chlorophaea* f. *conistea* but differs morphologically by the lack of soredia.

## II. DISTRIBUTION

According to Evans (1944), the Connecticut specimens in the Yale herbarium were 87 percent *C. grayi*, 8 percent *C. cryptochlorophaea*, and 5 percent *C. chlorophaea*. In contrast, Thompson (1967) reports that 41 percent of the Wisconsin specimens in his collection were *C. chlorophaea*, 22 percent *C. chlorophaea*, 20 percent *C. conista*, 13 percent *C. grayi*, and 4 percent *C. merochlorophaea*.

In Ohio, Taylor (1968) reported *C. grayi* from 45 counties, *C. cryptochlorophaea* from 38 counties, *C. pyxidata* from 32 counties, *C. conista* from 32 counties, and *C. chlorophaea* from 25 counties. He also mentioned that *C. grayi* was by far the most common species encountered in Ohio, being present in 62 percent of the 427 packets collected.

On the basis of a bar graph published by Wetherbee (1969) in his study from Northern Michigan, approximately 38 percent of his specimens were *C. grayi*, 35 percent *C. chlorophaea*, 20 percent *C. cryptochloraphaea*, and 8 percent *C. merochlorophaea*. Wetherbee proposed that ecological factors were more important in determining distribution than geographic location, since he recorded a substrate preference for bark in *C. grayi*, and a soil preference in *C. cryptochlorophaea*.

Kristinsson (1971), in his North Carolina study, reports *C. grayi*, *C. cryptochlorophaea*, *C. conista*, *C. chlorophaea*, and *C. perlomera*. Although he does not give percentages of occurence, he does illustrate the counties where each species was collected.

He stated that *C. chlorophaea* and *C. conista* are rare and limited to the mountains and piedmont, while *C. perlomera* was found exclusively on the coastal plain. In contrast, both *C. grayi* and *C. cryptochlorophaea* were found in all three geographical areas of the state, with *C. grayi* most commonly collected.

Two additional pertinent studies to be noted for the midwest are by Mertz (1972) for Turkey Run State Park in

West-central Indiana and by Skorepa (1973) for Southern Illinois. Both identified *C. chlorophaea, C. conista, C. cryptochlorophaea, C. grayi, C. pyxidata,* and *C. pleurota,* but neither reported the frequency of occurence for these species.

## MATERIALS AND METHODS

### I. LOCATION OF COLLECTIONS

A total of 591 specimens of Cladonias with cup-shaped podetia were collected in Illinois, Indiana, and Wisconsin. Four areas were collected in Illinois: Jackson Hollow, Pope County, in southern Illinois (58 specimens); Touch of Nature interpretive center and Giant City State Park, Jackson-Williamson Counties, in southern Illinois (82 specimens); Sand Ridge State Park, Mason County, in west-central Illinois (59 specimens); and Starved Rock State Park, LaSalle County, in northern Illinois (107 specimens). A collection trip to Pere Marquette State Park, Jersey County, in south-western Illinois was made, but no cup Cladonias were encountered.

There were three areas collected from in Indiana: Koontz Lake, Starke County, in northern Indiana (95 specimens) Turkey Run State Park, Parke County, in west-central Indiana (81 specimens); and Fern Cliff area, Putnam County, in west-central Indiana (35 specimens).

Collections from Wisconsin were made by Dr. Alan Parker, University of Wisconsin-Waukesha, and the five areas collected from were: Whiteford Farm, Marquette

County, in south-central Wisconsin (11 specimens); Lone Rock DNR Unit, Richland County, in south-western Wisconsin (5 specimens); a county roadside park, Sauk County, in south-central Wisconsin (6 specimens); Tamarack Road, Walworth County, in south-eastern Wisconsin (17 specimens); and Palmyra Prairie, Waukesha County, in south-eastern Wisconsin (35 specimens). All specimens are deposited in the lichen collection of Dr. W. Whiteside, which is housed in the Stover Herbarium, Eastern Illinois University, Charleston, Illinois.

## II. COLLECTION AND SCREENING TECHNIQUES

The lichens were removed from the substrate with a knife and placed in consecutively numbered envelopes. Three to five podetia were included in each sample in order to provide adequate material for chromatography and confirmation by one or more crystal tests, if necessary. The samples were initially screened by illumination under an ultra-violet light (Chromato-vue, Model CC-20; Ultraviolet Products, Inc.) to separate out the U-V positive specimens. The U-V positive specimens were then further divided according to brightness of fluorescence, with the brighter samples tentatively determined as *C. grayi* and those showing less fluorescence as *C. cryptochlorophaea.* Initially, only these two U-V positive types were to be chromatographed, but it was later decided to chromatograph all specimens, since it became apparent that the degree of fluorescence was not always an accurate indicator of the lichen acid content. Grayanic acid always showed

a very bright fluorescence in all specimens but cryptochlorophaeic acid was variable, with a range from intense fluorescence similar to the type produced by grayanic acid down to specimens which appeared U-V negative.

Of the 63 specimens identified as *C. cryptochlorophaea*, 36 were not initially determined to be *C. cryptochlorophaea* by U-V light illumination. Five of the 36 specimens were thought to be *C. grayi* and the other 31 were interpreted as being U-V negative. This data suggests that the amount of cryptochlorophaeic acid present is highly variable from specimen to specimen, and this is shown by the variability in fluorescence. All specimens of *C. grayi* fluoresced very brightly with no perceivable variation.

## III. IDENTIFICATION OF LICHEN SUBSTANCES

Thin layer chromatography (TLC), as described by Culberson (1972), was the major technique used for the determination of the lichen substances in the specimens. It is a relatively easy and precise method which is described in the following paragraphs.

A podetium from a sample is placed on a slide on a warming tray (C.S. and E. Slide Warmer; Clinical Scientific Equipment Co., Melrose Park, IL, with the temperature dial set at 4.4 for this model). A drop or two of acetone is placed on the podetium to extract the lichen substances. Then a capillary tube is used to remove the lichen acid extract from the slide and to spot it on a silica gel

chromatographic plate (Brinkman Chromatography, Brinkman Instruments, Cantiague Road, Westbury, N.Y.). A cardboard template with nineteen holes in it was employed to standardize spotting locations and numbers. Sixteen specimens and three controls were spotted on each plate, with the controls being two, ten and eighteen. The control organism was *Parmelina perforatum* (Jacq.) Mass. because it contains both norstictic acid and atranorin. Norstictic acid has a low RF value of 4, while atranorin has a high RF value of 7, with most other acids falling between the two.

Three plates are spotted identically and exposed to three solvents represented by the letters A, B, and C. The proportions of ingredients in each solvent, as prescribed by Culberson (1972), are (A) benzene-dioxane-acetic acid (180:45:5, 230 ml.); (B) hexane-diethylether-formic acid (139:80:20, 230 ml.); (C) toluene-acetic acid (200:30, 230 ml.). However, in solvent A, toluene was substituted for benzene due to its implication as a leukemia-causing carcinogen (Roberts, et. al., 1971). Prior to placing the plates for solvents B and C in the solvent tanks it is necessary to pretreat these plates for five minutes in 60 percent glacial acetic acid fumes, with the B plate then given an additional five minutes in 60 percent formic acid fumes (Culberson, 1972). No pretreatment is required for the plate to be placed in solvent A. The tanks used for the acid fumes were

29.5 X 9.5 X 22 cm. in dimension (Brinkman Instruments), and the tanks for the solvents were 22 X 10 X 22 cm. in dimension (3-Desaga Heidelberg, Germany). Two layers of watch glasses were placed in the bottom of the acid fume tanks to prevent the plates from coming into direct contact with the acids. One layer of watch glasses was placed in the solvent tanks to prevent the spot line from being immersed in the solvent, which could cause dissipation of the substances in the spots. The plates were kept in the tanks until the solvents were about 1 cm. from the top of the plate, then removed and air dryed under a hood to draw away the solvent fumes. The plates were then viewed with a U-V light and the fluorescing spots (i.e., grayanic-cryptochlorophaeic acids) were circled with a pencil. Since the silica layer on the plate is white, other non-fluorescing acids and substances can also be distinguished and marked. After marking, the plates were sprayed with a 10 percent sulphuric acid solution and then baked in an oven at 110°F for ten minutes (Precision Gravity Convection Oven; GCA Corporation). The spraying of the sulphuric acid was done under a hood in order to draw the fumes away. These last two steps make the lichen substances visible under normal incandescent light. After cooling, the plates can be stored for further use.

After the lichen substances had been tentatively identified on the basis of RF values, they were confirmed by crystal analysis using the procedure described by Thomson

(1967) and Taylor (1968). One podetium is removed from a sample and placed on a new slide. A drop or two of acetone is put on the podetium to extract the lichen substances, and the podetium is then removed. Once the extract is dry, a drop of the appropriate reagent for a suspected lichen substance is placed on the extract, followed by a new cover-slip. Then, gentle heat is applied by passing the slide quickly over an alcohol flame, in order to dissolve the lichen substances into the reagent. As the reagent cools, the characteristic crystals for the lichen substance will form. The following list gives the abbreviations and proportions of reagents used in this technique:

G.A.W. - 1:1:1 glycerine, alcohol, water

G.E. - 1:3 glycerine, glacial acetic acid

G.A.Q. - 2:2:1 glycerine, alcohol, quinoline

G.A.An. - 2:2:1 glycerine, alcohol, aniline

G.A.o-T. - 2:2:1 glycerine, alcohol, orthotoluidine

The G.A.W. reagent is used for identification of both grayanic acid, which appears as straight, needle-like crystals, and cryptochlorophaeic acid, which forms curved, linear crystals. For atranorin, the G.A.o-T. reagent is used. Atranorin forms long, curving, yellow crystals with characteristic branched tips. The G.E. solution is the preferred reagent for both usnic acid and zeorin.

## RESULTS

The four species encountered and number of collections

for each species are given in Table 1. Each species is further divided into groups according to whether or not they contain an accessory substance (such as fumaroprotocetraric acid). The collecting areas are shown in Figure 1. It can be seen from Table 1 that of the 63 specimens determined to be *C. cryptochlorophaea,* 33 or 52.4 percent contained 12 atranorin. This firmly establishes the presence of atranorin-containing chemotaxon reported by Cunningham (1982). The distribution of this chemotaxon appears to be widespread since at least one area from each of the three states where specimens were collected is represented with an atranorin-containing sample, as shown in Figure 2.

Four of the eight collection areas where *Cladonia cryptochlorophaea* was encountered contained specimens with cryptochlorophaeic acid and atranorin, as well as specimens with only cryptochlorophaeic acid. Since both variants were found in relatively equal proportions, it appears that there is no dominance of either type. Of the four remaining areas with only one variant found, two had less than five specimens of *C. cryptochlorophaea* collected. Collection of additional specimens would undoubtedly increase the chance of encountering both types. Fumaroprotocetraric acid was present in 43 of the 63 (68 percent) specimens of *C. cryptochlorophaea* and seemed to show no relationship to the presence or absence of atranorin.

Of the 591 specimens collected; 343 (58 percent)

were determined to be *C. grayi*, 112 (19 percent) were identified as *C. chlorophaea*, and 63 (11 percent) were determined to be *C. cryptochlorophaea*. *C. grayi* was by far the most common species collected, with 324 of the 343 collections lacking fumaroprotocetraric acid (see Figure 3). This great abundance of *C. grayi* parallels Taylor's findings for Ohio, where he reports this species in 62 percent of the collections of brown-fruited cup Cladonias for that state. In contrast, Thomson reports that for this same group only 13 percent of his collections from Wisconsin are *C. grayi*. The data obtained from this present study agree closely with these authors, since *C. grayi* makes up only 25 percent of the collections from Wisconsin, while Illinois and Indiana have higher percentages, approximately 75 and 86 percent respectively. These percentages were computed without *C. pleurota* so that the data are comparable to those given by Taylor and Thomson.

*C. pleurota* had the second highest number of collections and was found in all Illinois and Indiana areas except Turkey Run State Park (see Figure 4). However, Mertz reports finding *C. pleurota* at Turkey Run so it is present at this location but was not collected by the author. No specimens of *C. pleurota* were found in the Wisconsin material, which corresponds with Thomson's opinion of this species as having a greater concentration in southern areas.

In very loose sandy areas, such as Sand Ridge State Park, Illinois, and Koontz Lake, Indiana, *C. grayi* was the

predominant organism, outnumbering all other species 9:1 or greater. On harder substrates such as the sandstone found at Jackson Hollow, Giant City State Park, and Starved Rock State Park in Illinois, and Fern Cliff in Indiana, *C. pleurota* was found in greater numbers than *C. grayi*. This substrate difference may possibly be a factor in determining the abundance of these two species.

*C. chlorophaea* was found in all three states and in all but two collection sites (Figure 5.) The data from Starved Rock State Park in north-central Illinois show that 32 specimens of *C. chlorophaea* were collected (see Table 1.), along with 30 specimens of *C. grayi* and 45 specimens of *C. pleurota*. This is a much higher proportion of than that found in any of the more southern collection areas in Illinois and Indiana. The Wisconsin data also show high proportions of *C. chlorophaea*. These data coincide with Thomson's report of a greater number of *C. chlorophaea* specimens in relation to other cup Cladonias in the northern United States. Kristinsson (1971) reports *C. chlorophaea* as being rare in North Carolina, which coincides with the low numbers of this species collected from southern Illinois and Indiana.

## SUMMARY

The major purpose of this study was to determine the distribution in Illinois, Indiana, and Wisconsin of an antranorin-containing variant of *Cladonia cryptochlorophaea,* which was discovered in 1982 from Coles County, Illinois, by Cheryl Cunningham. The TLC method and microcrystal tests were utilized for the identification of lichen substances. Specimens of *C. cryptochlorophaea* containing atranorin were encountered in all three states. The presence or absence of atranorin was independent of that of fumaroprotocetraric acid, another accessory substance sometimes found in this species.

A second objective was a distributional study of the cladonias having cup-shaped podetia in this same three state area. *Cladonia grayi* was the most frequently encountered chemotaxon.

For *Cladonia chlorophaea,* there was a higher frequency in Wisconsin than the more southern areas in Illinois and Indiana. *Cladonia pleurota* showed a preference for harder substrates such as sandstone over loose sand or sandy soil. *C. cryptochlorophaea* was always collected in low frequences.

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TABLE 1: COLLECTION AREAS AND SPECIES COMPOSITION OF CUP CLADONIAS

| Collecting Site | Total No. Collections | *C. cryptoch orophaea* + Atranorin + Fum.* | *C. cryptoch orophaea* + Atranorin - Fum. | *C. cryptoch orophaea* - Atranorin + Fum. | *C. cryptoch orophaea* - Atranorin - Fum. | *C. grayi* + Fum. | *C. grayi* - Fum. | *C. chlorophaea* | *C. pleurota* |
|---|---|---|---|---|---|---|---|---|---|
| Illinois | | | | | | | | | |
| Jackson Hollow; Pope County, IL 8/18/83 | 58 | | 9 | | | 4 | 24 | 0 | 21 |
| Giant City St. Pk.; Touch of Nature Int.- Jackson-Williamson Co. IL 8/19/83 | 82 | 4 | 1 | 7 | | 11 | 41 | 1 | 17 |
| Starved Rock State Park LaSalle County, IL 10/07/83 | 107 | | | | | | 30 | 32 | 45 |
| Sand Ridge State Park Mason County IL 10/15/83 | 59 | | | | | 3 | 55 | | 1 |
| Pere Marquette State Park Jersey County | 0 | | | | | | | | |

*Fum. - Fumaroprotocetraric acid

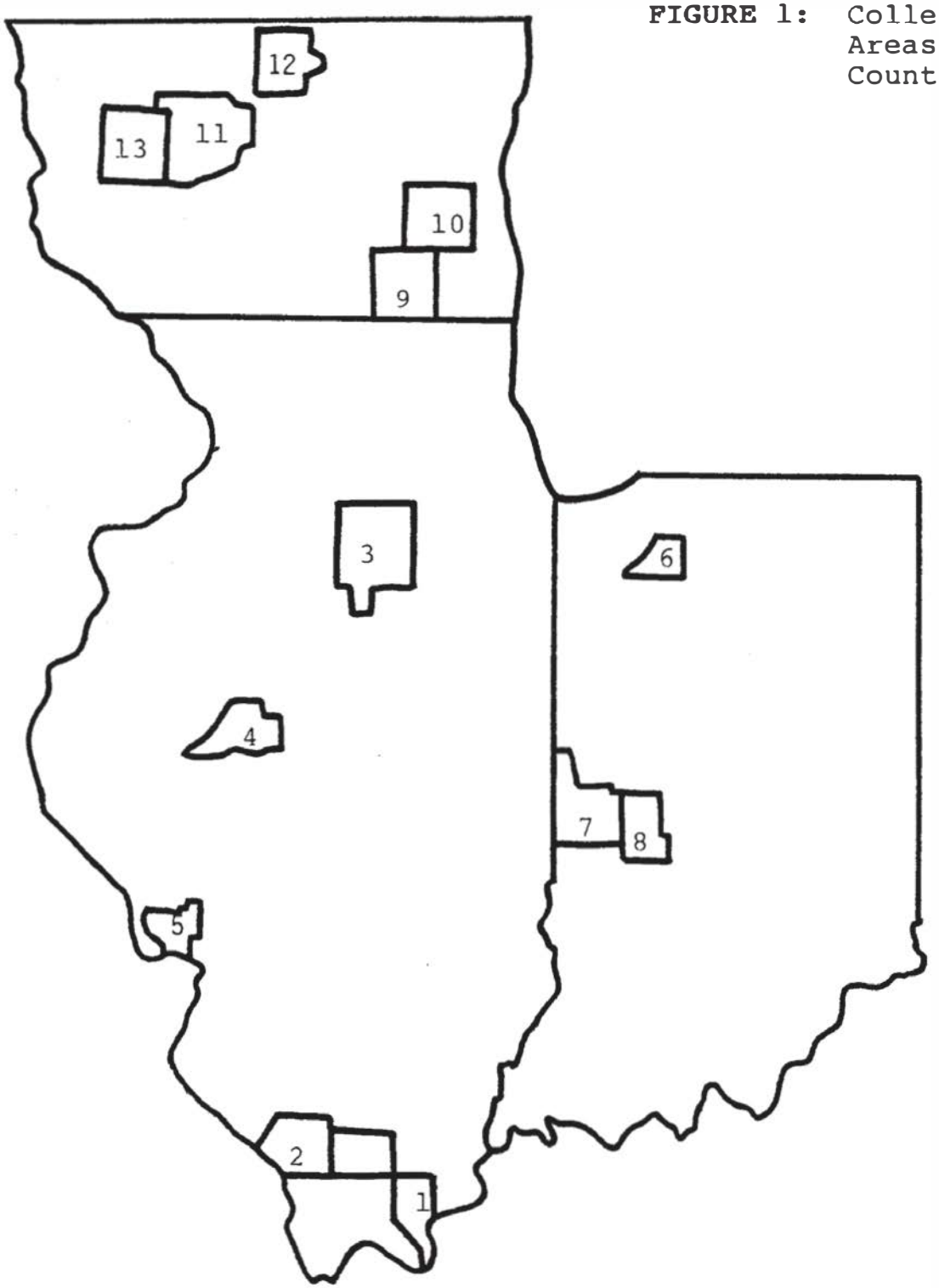
| Collecting Site | Total No. Collections | *C. cryptochlorophaea* + Atranorin + Fum.* | *C. cryptochlorophaea* + Atranorin - Fum. | *C. cryptochlorophaea* - Atranorin + Fum. | *C. cryptochlorophaea* - Atranorin - Fum. | *C. grayi* + Fum. | *C. grayi* - Fum. | *C. chlorophaea* | *C. pleurota* |
|---|---|---|---|---|---|---|---|---|---|
| INDIANA | | | | | | | | | |
| Koontz Lake Starke County IN 9/04/83 | 95 | | 1 | | | 1 | 85 | | 8 |
| Turkey Run State Park Parke County IN 9/23/83 | 81 | | | 7 | 1 | | 68 | 5 | |
| Fern Cliff Putnam County IN 10/22/83 | 35 | 4 | | | 3 | | 5 | 3 | 20 |
| WISCONSIN | | | | | | | | | |
| Tamarack Road Walworth County, WI 11/13/83 | 17 | 4 | | 2 | | | 1 | 10 | |
| Palmyra Prairie Waukesha County WI 11/13/83 | 35 | 5 | 5 | 9 | | | 2 | 14 | |
| County Roadside Park Sauk County WI 10/16/83 | 6 | | | | | | 6 | | |

* Fum. - Fumaroprotocetraric acid

| Collecting Site | Total No. Collections | *C. cryptochlorophaea* | | | | *C. grayi* | | *C. chlorophaea* | *C. pleurota* |
|---|---|---|---|---|---|---|---|---|---|
| | | + Atranorin | | - Atranorin | | | | | |
| | | + Fum.* | - Fum. | + Fum. | - Fum. | + Fum. | - Fum. | | |
| Whitford Farm Marquette County, WI 10/8/83 | 11 | | | 1 | | | 2 | 8 | |
| Lone Rock DNR Unit Richland County, WI 10/16/83 | 5 | | | | | | 5 | | |
| Total Number of all Collections and Species | 591 | 17 | 16 | 26 | 4 | 19 | 324 | 73 | 112 |

*Fum. - Fumaroprotocetraric acid

**FIGURE 1:** Collection Areas and Counties




1. Jackson Hollow - Pope Co., IL
2. Giant City State Park - Touch of Nature Interpretive Center - Jackson-Williamson CO., IL
3. Starved Rock State Park - LaSalle Co., IL
4. Sand Ridge State Park - Mason Co., IL
5. Pere Marquette State Park - Jersey Co., IL
6. Koontz Lake - Starke Co., IN
7. Turkey Run State Park - Parke Co., IN
8. Fern Cliff - Putnam Co., IN
9. Tamarack Road - Walworth Co., WI
10. Palmyra Prairie - Waukesha Co., WI
11. County Roadside Park - Sauk Co., WI
12. Whitford Farm - Marquette Co., WI
13. Lone Rock DNR Unit - Richland Co., WI

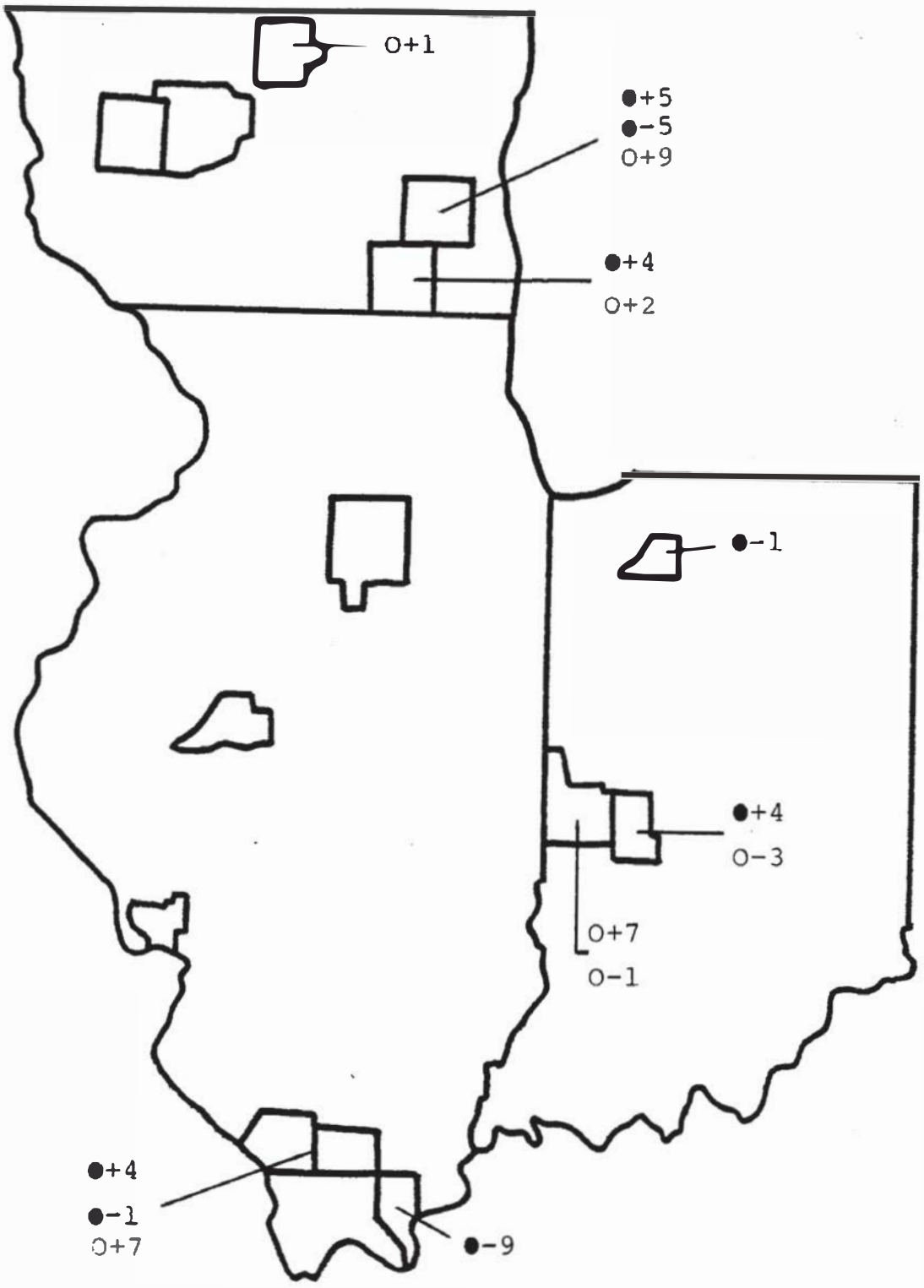



**FIGURE 2:** Distribution and Number of Specimens Collected of *Cladonia cryptochlorophaea*

| | |
|---|---|
| ● | Atranorin present |
| O | Atranorin absent |
| + | Fumaroprotocetraric acid present |
| - | Fumaroprotocetraric acid absent |

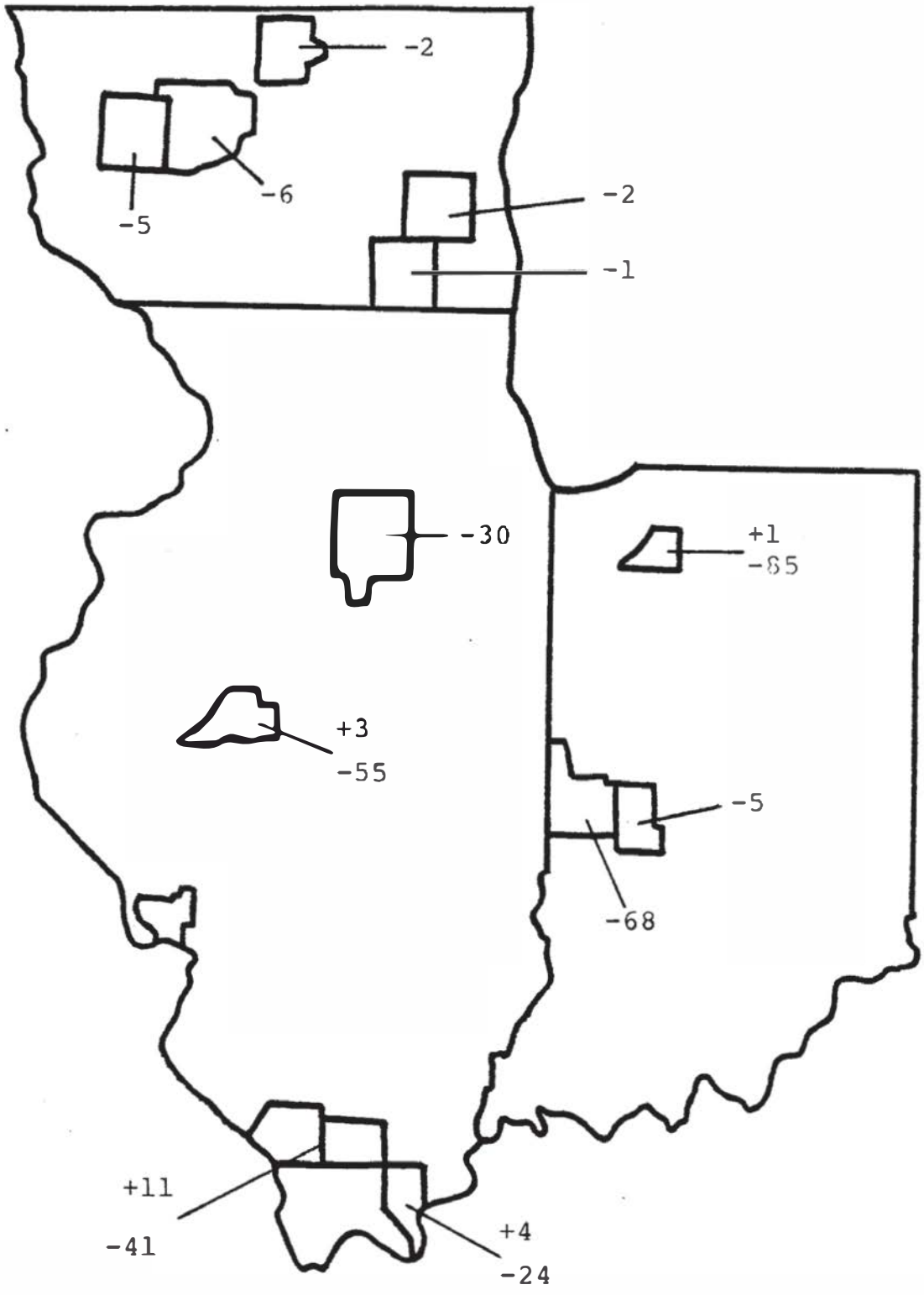



**FIGURE 3:** Distribution and Number of Specimens Collected of *Cladonia grayi*

\+ Fumaroprotocetraric acid present
\- Fumaroprotocetraric acid absent

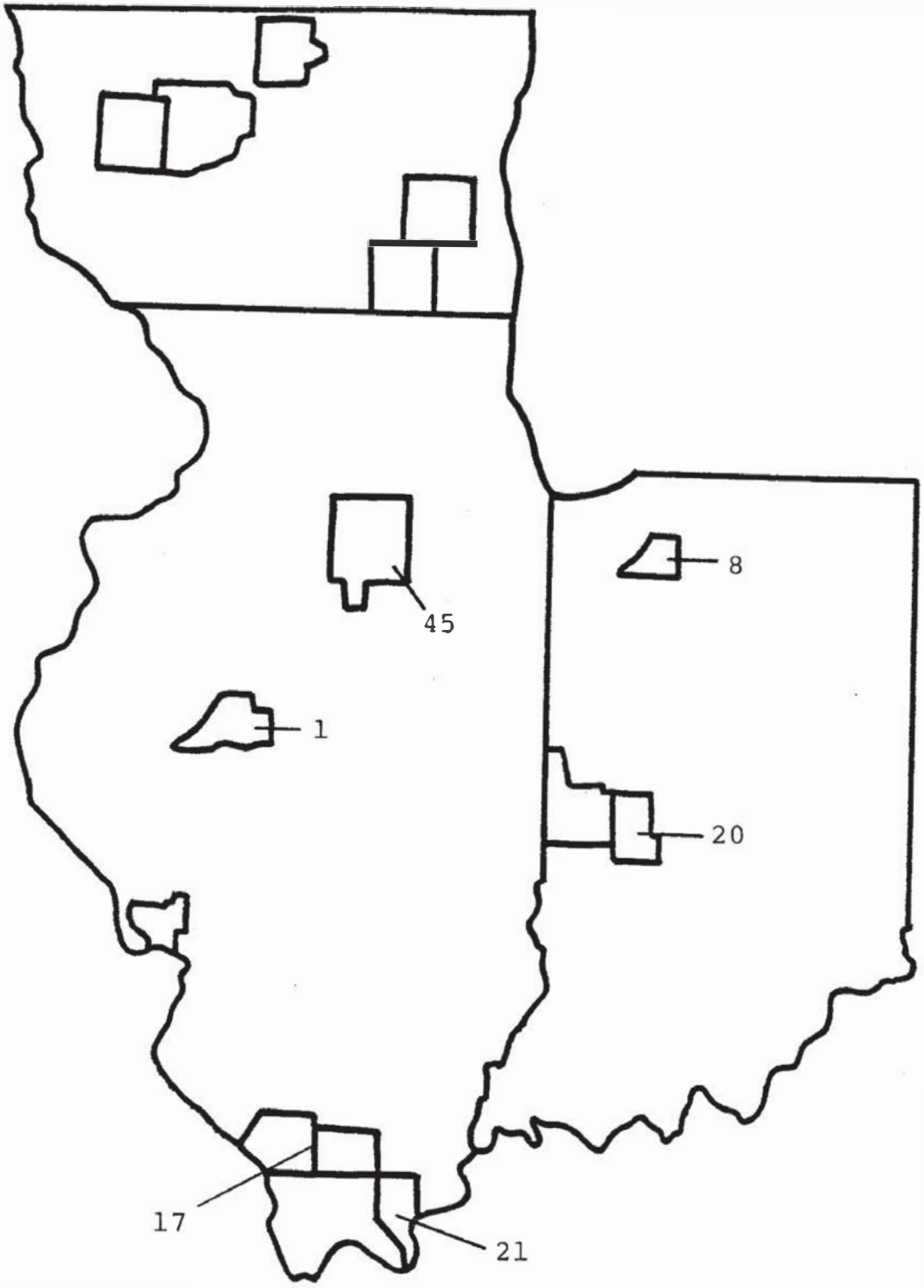



**FIGURE 4:** Distribution and Number of Specimens Collected of *Cladonia pleurota*

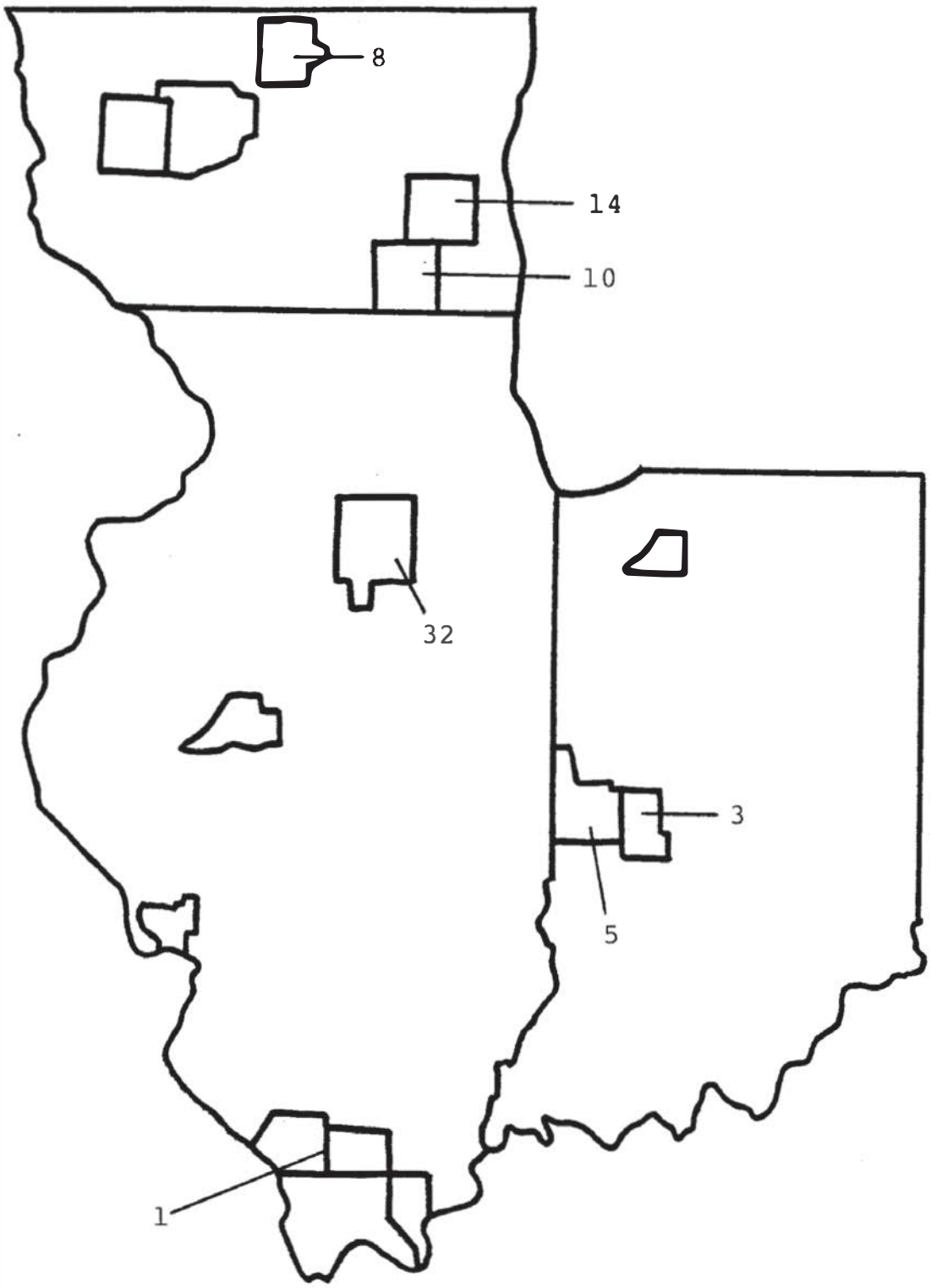



**Figure 5:** Distribution and Number of Specimens Collected of *Cladonia chlorophaea.*